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Strengthening Undergraduate Career Preparedness through Multidisciplinary Research Projects

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Abstract

Growing global and technological demands on industry have led to an increased emphasis on the educational training of undergraduate engineers to better equip them for engineering careers. This increased focus has resulted in a call for changes to the undergraduate engineering curriculum. Clemson University's undergraduate research program, Creative Inquiry (CI), can serve as an example of how to address some of these current educational challenges and create a culture of undergraduate research that benefits both academia and industry.

We believe that research opportunities which incorporate hands-on experiences for undergraduates across different disciplines will encourage skill development in areas directly related to current industry needs. The professional benefits for participants of multidisciplinary undergraduate research projects were evaluated through a case study of a project which took place from Fall 2010 to Spring 2012. The project team was comprised of students majoring in mechanical engineering, bioengineering, marketing, and nursing. Interviews with past members of the multidisciplinary team were able to elicit individual's perceptions of the team dynamic as decisions were made throughout the project. All past team members had graduated and many were employed in careers related to their majors at the time of the interviews. This allowed them to offer insights into how their experience on the project has impacted their current careers. Our study shows that multidisciplinary research projects can foster practical experience and encourage skill development in areas of communication and teamwork which directly impact how recent graduates approach their current careers.

Introduction

The National Academy of Engineering (NAE) recently identified 14 grand challenges for engineers to address in the coming century. This list includes topics related to sustainability, healthcare, standards of living, and security[1]. These grand challenges pose lofty goals for the engineering community, and meeting these goals will require a global perspective that incorporates problem-solving, communication, and leadership skills as well as collaboration among engineers and non-technical professionals. Traditional curricula for engineering students are rich in mathematical and computational analyses of concepts that can be applied to address these technical challenges. So, one objective for engineering educators is to also prepare students to be successful in diverse teams tasked with solving contemporary problems requiring perspectives and analyses from multiple disciplines. The American Society of Mechanical Engineers (ASME) proposed one approach to expand the scope of required graduates' skills in their 2030 vision for mechanical engineering education[2]. The vision recognizes deficiencies employers observed of early career engineers in solving contemporary problems. The ASME vision also identifies skills that will likely be required of future engineers as they address the immense scope of the NAE grand challenges.

The ASME vision for 2030 is motivated by survey data identifying important gaps between educators' and industry professionals' views of the skills early career engineers possess upon graduation[2]. In the survey, industry supervisors identify weak communication skills, weak problem solving ability, and a lack of practical experience as common flaws of recent mechanical engineering graduates[2]. However, a significantly smaller percentage of mechanical engineering educators identified these skills as "weak". For example, 52% of employers reported "weak" communication skills while only 22% of educators saw communication skills as a weakness in recent graduates[3]. Recent mechanical engineering graduates rated their own communication skills even stronger; only 17% identified them as "weak"[3]. Survey data identified a similar trend in perceptions of problem solving ability[3]. This survey data illustrates a perceived gap between what educators believe mechanical engineering students are being taught and the skills these students are using successfully when they enter the work force. Properly designed undergraduate research experiences is one approach to bridge this gap while addressing the ASME vision's call for the addition of more experience-based components to mechanical engineering education.

Practical Experience through Undergraduate Research

Studies on the outcomes of undergraduate research have suggested that participation in research experiences can offer significant benefits for students[4,5,6]. A number of opportunities exist for undergraduates to gain hands-on research experience beyond the required curriculum including National Science Foundation Research Experiences for Undergraduates (NSF-REU) [7], Summer Undergraduate Research Experiences (SURE)[8], as well as university specific research programs. The Creative Inquiry (CI) program at Clemson University takes a novel approach to undergraduate research experiences without requiring major changes to the curriculum. The program employs a unique funding model that addresses some of the challenges identified by the ASME 2030 vision including insufficient funding and faculty buy-in[9]. Each project is internally funded by the office of undergraduate studies. CI projects are awarded $300 for each student on the team with a semester maximum of $2000 per team. This funding model provides an incentive for faculty to become involved as it allows for the purchase of research supplies, travel expenses, student training, and even faculty professional development. The program encourages faculty to explore new topics or areas of research, set-up laboratory experiments and equipment, and utilize undergraduate students to expand viable research avenues. The flexibility of the program makes it beneficial for tenure-track as well as non-tenure track faculty while giving students at all stages of their academic careers the opportunity to participate in hands-on research projects.

CI projects are offered in each academic discipline, many of which offer a number of projects from which students can choose. The program encourages student-centered projects that allow undergraduates to explore a topic of interest while developing a sense of independence. According to the CI Spring 2014 survey data, approximately 20% of projects result from ideas generated by students who then approach a faculty member to be the project mentor. Students receive course credit for their participation which can be applied to their major requirements in some instances. Creative Inquiry typically funds over 450 projects each semester. During the 2013-2014 academic year, 5291 undergraduate students (nearly 4% of the university's undergraduate population) were enrolled in CI projects.

Case Study of a Multidisciplinary Project

One distinctive Creative Inquiry project, which called for the design skills of mechanical engineers, implemented a multidisciplinary approach to designing a system requested by practicing nurses and hospital child life specialists. A new process and device was needed to stabilize the arm of pediatric patients while nurses performed venipuncture procedures, such as drawing blood. The student team was formed in Fall 2010 and the project continued for 4 semesters. The project team was composed of students majoring in mechanical engineering, bioengineering, marketing, and nursing, and the project was facilitated by faculty members in the Nursing and Mechanical Engineering Departments at Clemson University. Students were enrolled in the project on a semester basis, and new team members were added throughout the project to help meet growing demands as it moved forward, making the team dynamic in terms of both academic discipline and grade level. The project was advised by faculty, but the project itself was student led.

Hospital personnel provided the team with a broad objective which the team members then had to develop into a detailed list of prioritized criteria and constraints. The device had to be portable, able to be set-up in about one minute, adaptable to different patient arm sizes and positions, as well as able to be mounted to hospital beds of varying shapes and heights. The multidisciplinary team collaborated in identifying critical objectives, designing the system, developing a prototype, demonstrating the process and device to medical professionals for assessment, and filing for a provisional patent on their design. This team model not only encouraged student project ownership and the development of collaboration and leadership skills, but it resulted in less demand on the faculty mentors. A student team leader was in charge of delegating tasks to each team member, helping to define team objectives, leading team meetings, and keeping track of expenditures. The team met every week with the nursing and mechanical engineering faculty mentors to evaluate progress from the previous week and plan for the following week. Effective communication at each meeting kept team members from each discipline engaged and working toward meeting project goals.

A Qualitative Approach to Investigating the Team Dynamic

This study employs qualitative data collection, analysis, and reporting techniques to provide a rich description of what it was like to be a member of this multidisciplinary team. Semi-structured interviews were conducted with past team members and interview recordings were transcribed verbatim. Study findings are reported in narrative form incorporating exact quotes from participants. This use of participant quotes to help speak to an experience or phenomenon aligns with the traditional practice of qualitative research[10]. These quotes are purposively interwoven into the narrative, rather than reported at the end as a list of quotes, because the participants' words themselves offer perspective that only a member of the multidisciplinary team can portray.

During semi-structured interviews, team members (names reported as pseudonyms) from various disciplines offered unique perspectives about the project and interpretations of the multidisciplinary nature of the project. The interviews revealed the specific ways in which the multidisciplinary dynamic of the team was evidenced as decisions were made while the project moved forward.

Deanna, a Bioengineering major, was one of the initial members of the project team and served as the team leader. She described the team's first visit to the hospital where they met with the hospital's child life specialist whose job is to make young children more comfortable during their stay in the hospital. Deanna described how a child life specialist helps make a child more comfortable,

> "If they[the child life specialists]are noticing a child in their hospital bed is scared of a certain machine, they might find something to put on it to make it less scary…"

The child life specialist, along with hospital nurses, explained the need for a device to help stabilize a child's arm during intravenous procedures such as drawing blood. The students took measurements of two different hospital beds typically used for these procedures and made a list of objectives that needed to be addressed in the design to meet the needs of hospital staff. The marketing major on the team, Catherine, described how the group moved forward as members from each discipline put the project into perspective,

> "'Alright, the nurses think that this is what it [the device] needs to be able to do. Engineers, how do we do it? What can we build, how can you design something for us that can meet these specifications or better specifications', if they could think of something like that. Then I was the person over here saying, 'That sounds good, you can build that, but you need to spin that differently and you need to promote it like this and you need to say it will do this.'"

One of the mechanical engineering students, Matthew, described the first prototype developed by the team based on the list of device requirements.

> "So, originally we started out with just some PVC pipe and some two-by-fours and just random pieces of wood and just made a rough design."

He explained that design iterations were mainly motivated by feedback from the nursing and the bioengineering students who suggested adding more "creature comforts", like softer materials, as well as making the device easier to clean. Matthew went on to explain that sometimes each discipline had to give a more in-depth explanation of their decisions in order to answer questions from teammates with different backgrounds. He gave an example of a question the mechanical engineers were asked,

> "…'Why can't we just do, just kind of glue them together?' And we [the mechanical engineers] are like, 'Well, your strength of that adhesive is going to deteriorate over time so it would be better to kind of, if you have a metal, fuse it with a weld because that will hold longer.'"

Students from other disciplines often had to explain their motivations to the mechanical engineers as well,

> “We [the mechanical engineers] were sitting there thinking, ‘Why do you need to, why can’t you just hold an arm down? Why do you need to have it clamped in a system?’”

As the project moved forward, team members utilized more creative ways of answering each other’s questions. They would often develop simple prototypes from everyday items to help communicate their ideas to the rest of the team. A mechanical engineering student on the team, Melissa, was in charge of making a sturdy, movable base for the device. She explained how she demonstrated her idea for the base to the rest of the team,

> “…so pretty much what I did is I just put toilet paper rolls together and then I just cut out cardboard and showed the concept of the base of it [the device]…”

Physical representations, either through software drawings or simple prototypes, played a key role in facilitating clear communication among all members of the team as well as providing the students with practical, hands-on experiences. To meet the team objective, it was necessary for each student to communicate to all members of the team, and this practice impacts how past team members approach their current careers.

Professional Benefits to Students

At the time of the interviews, all project team members had graduated and many were employed in careers related to their majors of study. This allowed them to offer insights into how their experience on the project has impacted their current careers.

Deanna, the bioengineering team member and student team leader, is currently enrolled in physician assistant school. Reflecting back on her experience in the project, she said,

> “Well, I think I actually took a lot more away from that project looking back on it in the last year or so than you realize, like, being on it…”

After graduation Deanna worked as a clinical research coordinator before starting physician assistant school. Her job as a clinical research coordinator involved interacting with patients and communicating with both physical therapists and physicians. She described having to determine where to direct patients’ questions based on whether the physical therapist or the physician was more knowledgeable on the topic. She identified the “organization”, “management”, and “communication” skills she gained from her experience on the project as being relevant to her success as a clinical research coordinator and to her future work as a physician’s assistant.

The marketing major, Catherine, is currently employed by a chemical company where she interacts daily with engineers and scientists. She was able to articulate how her experience in this multidisciplinary project has directly prepared her for her current job and for experiences outside her job,

> “…This was a really good chance to build skills you need to learn how to work with people who are different from you. And whether or not I ended up in a science company or something like that, I think that is just incredibly valuable for everyone to know

because in daily life, you are going to have to interact with people of very different personality styles, different interests, all of that. And so I think a huge part of this project was just kind of learning what makes other people tick, figuring out how to relate to that even when you think you can't."

Catherine not only identified that she gained "interpersonal skills" from her experience on the team, but she also believed that she gained more confidence in her abilities through practical experience in patent research,

> "It [doing patent research for the team as a junior in college] definitely made me more confident for when I go into the workplace that if someone says, 'We need you to tackle this project' and it's outside of your comfort zone and you may not really know how to do it, I feel like I am prepared now."

Matthew, one of the mechanical engineers on the team, believed that "teamwork" and "communication skills" were important things he gained while working with people from different disciplines.

> "… I feel that communication is the key to anything that goes on, whether it be teamwork or your just daily operations wherever you are working because without the communication I mean nothing's really gonna get done. No one's gonna know what the progress is, no one's gonna know what they can do to improve a system if it needs to be improved or if it's fine as is."

He is currently working for a branch of the armed forces and was able to directly relate his experience on the multidisciplinary team to his current job responsibilities.

> "…Before I joined the Creative Inquiry, I was just like, 'OK I am going to attack this from traditional engineering standpoint. I've got this problem, what are my tools to fix it?' Whereas now I am thinking outside of that engineering box and thinking, 'OK, what really does the customer need? What really can I do to help them as far as providing a service or building a facility for them, whatever it is…'"

Team members with limited or no employment experience still shared some of the same perspectives regarding the benefits of being part of the multidisciplinary team, but were unable to identify specific instances where they had utilized these skills due to their lack of experience in the workplace.

Aaron, another mechanical engineering major, identified "communication skills" as an important aspect he learned from being part of this project.

> "The most important thing I think I learned from it [the project] was the ability to communicate with other people." "… we [the mechanical engineering students] were able to easily communicate amongst each other. We knew pretty much everything everyone else knew. But people outside of our field, we had to learn to be able to

communicate not only our designs to them but also how to understand what they were trying to ask us, and see if we are on the same page about everything."

Aaron went on to say that this type of communication across disciplines was not something he was exposed to in typical engineering courses.

> "And I don't feel that [interacting with students outside the engineering major] is something we actually got from any classes in my undergrad."

Aaron is currently working toward a Master's degree in mechanical engineering. He also explained that his experience on the pediatric arm stabilizer project directly influenced his future career goals. He is now interested in being part of an industry design team.

Melissa was only a freshman general engineering student when joining the team. The most valuable aspect of the project for her was the "experience" she gained from participating in hands-on research.

> "So that [the project] was like my first step in learning mechanical engineering and applying what I knew or what I didn't know and learning from it and then just kinda building on that to get, you know, a better co-op and then a better internship and then a good full-time job."

Melissa is currently working as a field engineer for an oil and gas company, but at the time of the interview had only been working in that position for one week.

Semi-structured interviews with participants on this multidisciplinary team allowed us to identify the team dynamic as decisions were made during the progression of the project. This qualitative approach also allowed us to elicit specific anecdotes reflecting how these experiences have directly impacted the team members' approaches to their current careers. Project participants from each discipline were able to identify skills they believe were unique to this multidisciplinary experience. Team members surmised that similar interactions with students from different disciplines would not have occurred within their regular undergraduate curriculum.

Conclusion

The outcomes of undergraduate research experiences, including identity development, clarification of career plans, and development of relationships with faculty and fellow students have been studied by a number of researchers[4,5,6]. We believe that hands-on, team based research also has the potential to help reinforce the importance of technical concepts and cultivate skills that will help bridge the gap between recent graduates' skills and the needs of industry. The novel Creative Inquiry program at Clemson University offers a mechanism for faculty and students to conduct funded research across disciplines. The unique internal funding model for CI encourages faculty to engage undergraduate students in research by providing funds for equipment, travel, and faculty professional development.

The flexible nature of this undergraduate research program is one approach to promote multidisciplinary communication and practical, hands-on research for undergraduates. The results of our case study suggest that working directly with students from different disciplines during undergraduate education can help lead to the development of a number of capacities including communication skills, interpersonal skills, and practical experience. These skills align with those identified by industry professionals in the ASME 2030 vision survey to be "weak" in many recent engineering graduates[2].

Project team members, especially those with employment experience, were able to directly tie the communication, teamwork, and interpersonal skills they attributed to the multidisciplinary project with their roles as employees. This case study suggests that undergraduate research across disciplines can supplement the undergraduate education and help mechanical engineering students obtain skills useful in addressing contemporary issues like those identified in the NAE grand challenges[1]. Further research can help reinforce these initial findings and expand the engineering education community's understanding of the outcomes associated with multidisciplinary undergraduate research teams.

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